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Geomorphic studies of landslides in the Tully Valley, New York: implications for public policy and planning ☆

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Abstract

On April 27, 1993, a large landslide in the Tully Valley, Onondaga County, NY, destroyed three houses and resulted in the evacuation of four others; it also triggered a loss of potable drinking water for about 15 homes north of the slide area and affected a total of 20 ha of land. In the 7 years following this slide, several studies have been conducted by federal and state environmental agencies and by local universities. The goal of these investigations has been to determine what caused this slide, document the history of past landslides in the region, and establish whether future slides are likely to occur. This paper reports on the results of these investigations and examines their effect on the Tully Valley community.

Keywords: Landslides; Tully Valley; Public policy and planning

1. Introduction

About midday on April 27, 1993, New York's largest landslide in the past 75 years occurred along the foot of Bare Mountain in the town of LaFayette in Onondaga County (Fig. 1). The landslide, a complex earth-slump/mudflow moved from the lower slope of Bare Mountain onto the valley floor, where it affected about 20 ha of land, destroyed three houses, necessitated the evacuation of several others, and covered 365 m of Tully Farms Road with as much as 5 m of remolded clay (Kappel et al., 1996; Kappel, 1997) (Fig. 2). Three individuals were rescued from their home by helicopter from the middle of the landslide area. Eventually, 15 homes lost their drinking water supply as a result of changes in local ground-water flow patterns. This paper describes the effects of the 1993 landslide, reports on the results of several follow-up investigations and geomorphic studies, and examines the implications of the landslide for public policy and planning in the Tully Valley community.

2. Geologic setting

Tully Valley is a north–south trending glacial trough along the northern limit of the Appalachian

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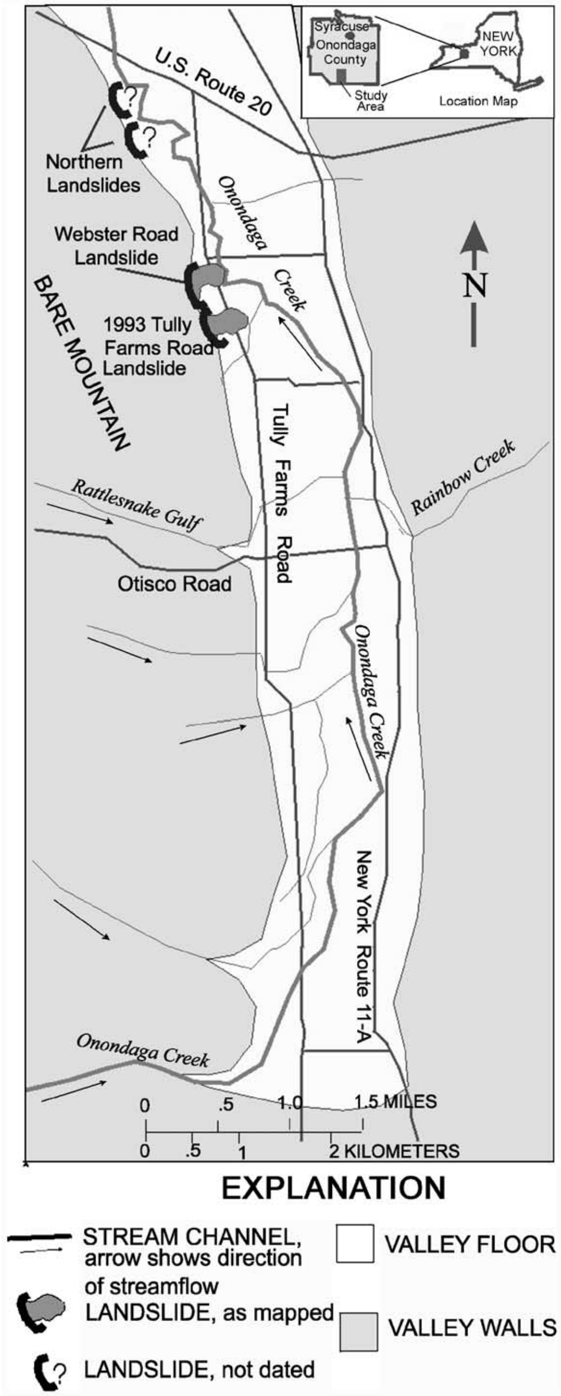

Fig. 1. Physical features in the Tully Valley, including the 1993 Tully Farms Road landslide, the Webster Road landslide, and two other landslide areas at the base of Bare Mountain.

uplands. The valley is about 10 km long and about 1.5 km wide. Onondaga Creek flows northward through the valley (Fig. 1) and drains to Lake Ontario. The valley walls consist of colluvium and glacial till over bedrock. The valley floor is generally underlain by more than 120 m of glaciolacustrine deposits associated with proglacial lakes that occupied the valley during glacial retreat about 14,000 years ago (Kappel et al., 1996; Gomes and Pair, 1997). These sediments grade upward through two sequences of postglacial alluvial gravel, sand, silt, and clay. The valley floor is mantled with an 18-m-thick unit of silt grading to clay. Some of the clay within this unit is saturated (Kappel et al., 1996).

3. Response to the 1993 Tully Farms Road landslide

Local and county officials and the state police immediately sealed off the slide area and rescued three people by helicopter. Homes adjacent to the slide were evacuated because the slide mass continued to move. This movement ceased within a few hours, but water flowing from the backscarp threatened to remobilize it. A team from the U.S. Geological Survey (USGS) working nearby provided technical assistance to local and state officials. Within the next 24 h, a response team was assembled consisting of personnel from State and County Emergency Management, the town of LaFayette, New York State Geological Survey (NYSGS), the U.S. Natural Resources Conservation Service (NRCS), the USGS, and Syracuse University (Kappel et al., 1996; Kappel, 1997).

3.1. Initial stabilization efforts

Initial efforts were directed toward stabilizing the landslide and draining the water discharging from fresh and brackish springs at the base of the main scarp area. Remediation activities (construction of diversion ditches and road clearing) were funded and directed by the NRCS through their Watershed Protection Program. The Onondaga County Department of Highways constructed all remedial works. Media coverage continued over the ensuing weeks, and several town meetings were held to keep the affected residents informed as to the stability of the

Fig. 2. Oblique view of the 1993 Tully Farms Road landslide taken April 30, 1993, 3 days after the slide. Debris moved towards the viewer and covered Tully Farms Road (dashed line) with as much as 4 m of remolded clay (modified from Wieczorek et al., 1998).

landslide and vicinity, how soon homeowners could safely return, when Tully Farms Road would be reopened, and when electric and telephone utilities would be restored.

3.2. Effects of the landslide on the Tully Valley community

Two weeks after the slide, the area was judged stable enough to allow most homeowners to return. Tully Farms Road remained blocked for several months, however, because of the high water content of the remolded clay. Utility lines were redirected from either end of the slide but still do not pass through the slide area. A local citizens group, the Tully Valley Conservation Association, quickly formed to secure financial aid as the economic losses were not large enough to warrant financial aid under federal or state disaster formulas. The citizens met with a Deputy White House Secretary who assembled representatives from several federal agencies. As a result of this meeting, affected landowners received small loans and grants to assist in either rebuilding or relocating. Within about a year, residents whose houses had been destroyed or severely damaged had relocated (Wieczorek et al., 1996). The closure of Tully Farms Road from April through September 1993 (Kappel et al., 1996) presented difficulties for local residents and for emergency service providers because the houses on the other side of Tully Farms Road could be reached only by a lengthy detour. About 10 landowners within and adjacent to the slide area received a property-tax reduction from the town of LaFayette as a means of providing further economic relief (Clay Smith, Town Supervisor, 1994–1999, Town of LaFayette, personal communication, 1999).

Soon after the 1993 slide occurred, 15 households north of the 1993 landslide lost their water supply from springs within the scarp of the Webster Road landslide area. These "reliable" springs remained dry during the summer of 1993, which forced the residents to haul water from other sources. At present, the springs flow from the late fall through spring but are dry the rest of the time. The town of Lafayette has sought alternative sources of water for these residents but found that connection to the county water-authority system or development of nearby water sources for a small community system would be too costly. Efforts to supply water for these residents continue, but the costs associated with a community-based water supply remain prohibitive.

3.3. Follow-up investigations

Members of the response team identified three major questions pertaining to the landslide: What caused it? Have similar landslides occurred here in the past? Are future landslides likely to occur? These questions were addressed through the following investigations.

(i) Ground-water conditions in the slide area were characterized through measurements of discharge and water quality of several freshwater and brackish-water springs located within the main scarp area (Kappel et al., 1996).

(ii) A dendrochronologic study was initiated to address changes in the quantity and quality of water discharging in a spring/wetland complex 300 m south of the 1993 slide area (Yanosky and Kappel, 1997a,b).

(iii) An inventory of landslides was compiled from aerial photography and field checked by the USGS not only for the Tully Valley but also for adjacent valleys in southern Onondaga County.

(iv) USGS scientists modeled landslide susceptibility and created a landslide susceptibility map for the region (Jäger and Wieczorek, 1994).

(v) Bedrock and surficial geologic maps (1:24,000 scale) of the Tully Valley and adjacent areas were prepared through the NYSGS–USGS cooperative STATEMAP Program (Brett et al., 1995; Pair, 1995). These efforts were intended to establish the bedrock and surficial stratigraphic framework, refine the distribution of the surficial units represented in the landslide susceptibility map, and permit detailed stratigraphic and chronologic studies of possible paleolandslide sites.

(vi) An analysis of the engineering properties of the landslide materials, water quality conditions in the hillside and bedrock aquifers, and pre- and post-slide subsurface conditions on the lower slope of Bare Mountain was undertaken through a National Science Foundation grant procured by the Department of Civil and Environmental Engineering at Syracuse University (Negussey et al., 1997). The goal of this study was to establish the key variables that contributed to the slope movement and failure.

(vii) Research was also conducted on the slope of Bare Mountain and within the landslide area by students from several universities for bachelor-level or masters-level theses. These studies (Burgmeier, 1998; Curran, 1999; Kawa, 1999; Walker and Pair, 1999; Morales-Muniz, 2000) included (a) development of several numerical models of the landslide to identify factors that led to the event; (b) analysis of the stratigraphic and geotechnical properties of the landslide materials; (c) several paleolandslide investigations; and (d) water quality studies of springs discharging within the landslide area.

4. Results of geomorphic studies

Studies initiated following the 1993 Tully Farms Road landslide have examined a number of topics. The results of several of the geomorphic investigations are summarized below.

4.1. Landslide inventory and landslide susceptibility map

USGS scientists recognized features suggestive of past landslides at 73 sites within a 415-km^2 area surrounding the Tully Valley. The landslides were classified by Jäger and Wieczorek (1994) into relative ages ranging from recently active to possibly Late Pleistocene. Spatial data on glacial-lake clays, slope steepness, and inferred locations of proglacial lakes were used to construct a landslide susceptibility map for the area. A logistic regression analysis was used to categorize landslide susceptibility into three classes: low, moderate, and high. The resulting map (Jäger and Wieczorek,1994) contains an explanation of how the map was developed and suggestions on its use. Copies were sent to governmental jurisdictions throughout southern Onondaga County as well as county planning and emergency management departments for zoning and land-use planning purposes (Wieczorek et al., 1996). This map has also become a reference document in the towns of LaFayette and Tully for land-use decisions (Wieczorek et al., 1996).

4.2. Bedrock and surficial geology maps

Bedrock mapping of quadrangles that encompass the 1993 landslide established the Upper Silurian–Middle Devonian stratigraphy for the Bare Mountain area (Brett et al., 1995). Further, based on aerial photographic interpretation and mapping of marker beds within the Devonian sequence, Fakundiny (1997) and Fakundiny and Brett (1997) have suggested the existence of a large rock-block slide preserved on Bare Mountain above the 1993 slide location. The age of this massive block slide remains uncertain but may attest to the instability of the slope of Bare Mountain.

Surficial geologic mapping has identified extensive areas of glaciolacustrine silts and clays. In several quadrangles, these fine-grained sediments are mantled by alluvium that has been mapped by Pair (1995) as a unit of Pleistocene alluvium over lacustrine silt and clay. This alluvial unit is exposed along the scarp of the 1993 Tully Valley Road landslide and has been mapped at the base of several slopes in adjacent valleys where several paleolandslides have been identified. Surficial mapping has also indicated the presence of colluvium on the slope of Bare Mountain that is not present along other slopes in the region. A series of abandoned rills and gullies within this colluvial unit were noted by Kappel et al. (1996) and Pair (1995, 1997). Significantly, these features are found below an area where the steep, bedrock-controlled slope is interrupted by several deep depressions oriented parallel to slope contours along much of the slope of Bare Mountain. Known locally as the "Grand Canal," this depression (and several others adjacent to it) appears to intercept runoff and route subsurface flow to the base of Bare Mountain (Kappel et al., 1996; Fakundiny and Brett, 1997).

4.3. Causes of the 1993 Tully Farms Road landslide

The follow-up studies referred to earlier identified several geologic, climatologic, and hydrologic factors as probable causes of the 1993 Tully Farms Road landslide. Changes in the slope at the base of Bare Mountain were noted prior to the slide. In 1991, the New York State Department of Environmental Conservation recorded the presence of a graben-like subsidence feature in the area now located along the south side of the 1993 slide. A local landowner also reported in the Fall of 1992 that water was discharging from this feature. Subsequently, the winter and spring of 1992–1993 provided above-normal precipitation and a massive blizzard in March 1993. April's snowmelt and above-normal precipitation were routed down the slope of Bare Mountain as subsurface flow within the bedrock and colluvium and fully saturated the alluvial sand and gravel at the base of the slope. This increased the pore water pressure in the confined silt, sand, and gravel overlying the glaciolacustrine sediments (Negussey et al., 1997; Kappel et al., 1996). Thus, the 1993 slide appears to have been caused by natural processes—specifically, excessive precipitation and snowmelt; and the presence of weak, glacial lake clay deposits at the base of Bare Mountain—and was triggered by unusual weather conditions (Pair et al., 2000).

4.4. Older landslides at the base of Bare Mountain

The surficial geologic mapping effort provided detailed checking and mapping of older landslides identified by Kappel et al. (1996) and by the landslide inventory of Jäger and Wieczorek (1994). The mapping effort resolved differences in interpretations of landform genesis and permitted the development of a chronologic framework for paleolandslides in the Tully Valley. One such paleolandslide, referred to as the Webster Road landslide, appears very similar in size and shape to the 1993 Tully Farms Road landslide. The Webster Road landslide is <90 m north of the 1993 slide location (Fig. 3). The scarp of the 1993 slide is from 9 to 15 m high and 427 m long, and the scarp of the Webster Road landslide is 12 to 15 m high and 366 m long. Another similarity is the topography—large, transported soil blocks, some of which had retained vegetation and trees, were found at the base of the slope and within the toe of the 1993 landslide (Fig. 4a) and have weathered such that the topography now resembles an area of hummocky ground at the toe of the Webster Road slide (Fig. 4b). Thus, the 1993 Tully Farms Road landslide and the Webster Road landslide are approximately the same size and probably displaced the same volume of material from the lower slope of Bare Mountain (Walker and Pair, 1999).

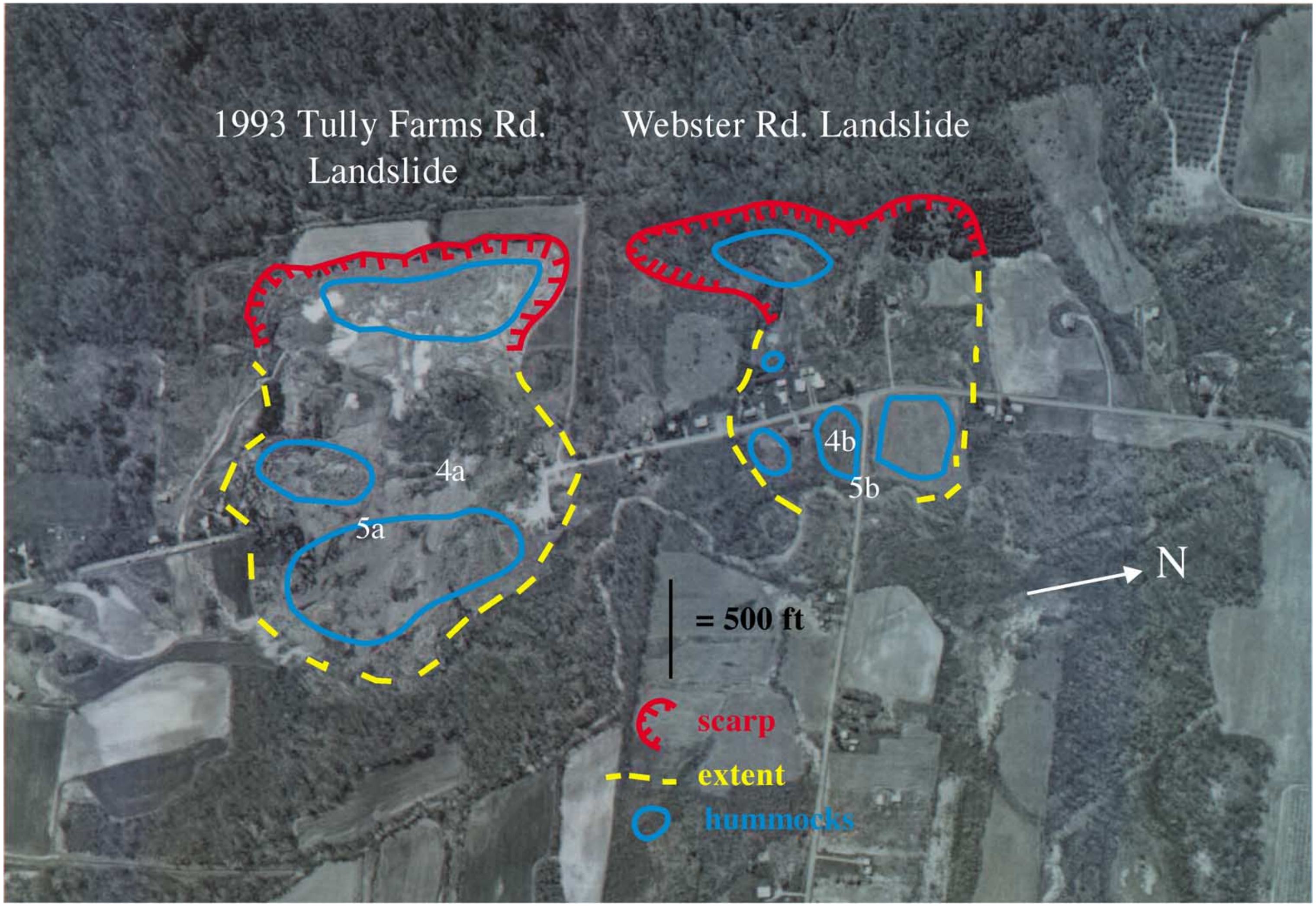

Fig. 3. Aerial view of the 1993 Tully Farms Road landslide taken May 1, 1993, 4 days after the slide occurred, and approximate location of Webster Road landslide to the north. Dashed lines indicate probable extent of the Webster Road landslide beyond Onondaga Creek, and numbers indicate the locations of Figs. 4 and 5.

(a)

(b)

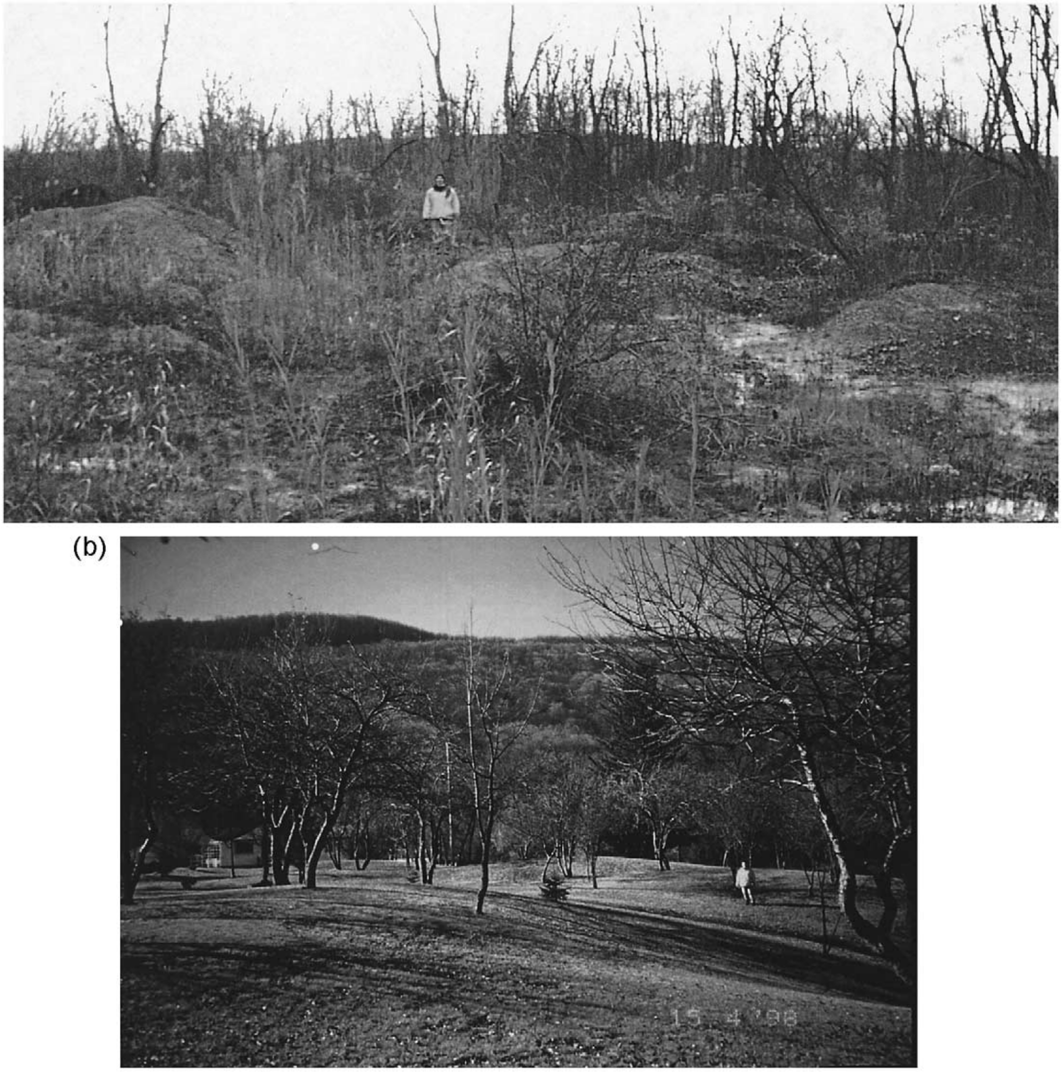

Fig. 4. Hummocks found at the toes of landslides: (a) 1993 Tully Farms Road landslide area; (b) Webster Road landslide areas. Locations are shown in Fig. 3.

The age of the Webster Road landslide was estimated from radiocarbon dating of peat-like organic and woody material found directly beneath mudflow deposits at several locations within the toe of the Webster Road paleolandslide. Radiocarbon ages of 6160±40 YBP (WW-2136) and 6110±50 YBP (WW-2137) on these organics indicate that the land surface and associated vegetation were buried by a mudflow at this time. The stratigraphy here is identical to that found in test pits dug within the toe of the 1993 slide (Fig. 5a,b) and seems to indicate that a landslide similar to that of 1993 occurred about 6100 years ago (Walker and Pair, 1999; Pair et al., 2000).

The Webster Road landslide described above may also have been caused by circumstances similar to the 1993 slide. Paleoclimate data obtained from sediment cores from several nearby Finger Lakes indicate highly changeable climate conditions. These data span

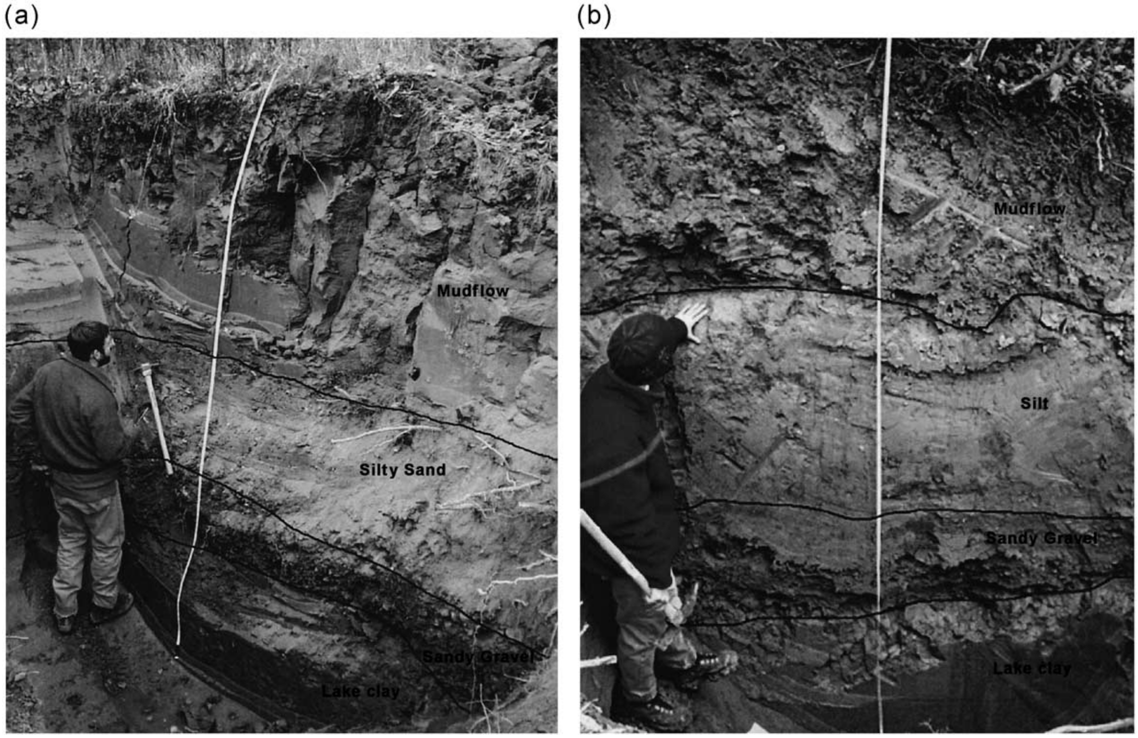

Fig. 5. Test pits dug in the two landslide areas: (a) Tully Farms Road pit just east of Tully Farms Road; (b) Webster Road pit on the south side of Webster Road. Locations are shown in Fig. 3.

postglacial time and show an overall trend of warm, dry climate conditions with cool, wet intervals. Information provided by sediment cores from the nearby Owasco and Cayuga Lakes has led some researchers to conclude that the Mid-Holocene Hypsithermal period (8.500–3.400 YBP) was one of the more changeable climatic periods in the Finger Lakes region (Dwyer et al., 1996; Mullins, 1998). Thus, one of these particularly wet episodes may possibly have triggered the Webster Road landslide 6100 years ago (Pair et al., 2000).

5. Community reaction to geomorphic studies in the Tully Valley

Interviews with former and present landowners affected by the slide and with several former and present governmental officials 6 years after the Tully Valley Road landslide portray the public's reaction to the steps undertaken after the 1993 landslide. Although these opinions and reactions are certainly not universal to all who live in the Tully Valley, they illustrate some of the challenges that scientists face when undertaking these types of hazard investigations. A sampling of the public reaction is provided below.

5.1. The landslide susceptibility map is only a model!

Conversations with present and former local officials have indicated that the actual use of the landslide susceptibility map has been small. As Highland (1997) pointed out, these types of studies can provide basic information for risk analysis if those at risk have an interest in the data. In the case of the landslide hazard in the Tully Valley, a former town supervisor has indicated that the landslide susceptibility map appears to be perceived more as a model and as a theoretical result than an actual document for use in planning (Clay Smith, Town Supervisor, 1994–1999, town of LaFayette, personal communication, 1999). Such a perception may be partly due to the sudden, unexpected nature of the landslide in contrast to those in other areas, such as the Pacific Northwest where such slides are expected and hazard response and mitigation programs are in place.

5.2. Are you sure the 1993 Tully Farms Road landslide was not caused by human activity?

Scientists have concluded that the 1993 slide was the consequence of a combination of natural processes and that, despite newspaper accounts speculating otherwise, no human activity, such as land-use changes (the backscarp of the slide was within a cultivated area at the base of a forested hillside) or brine field operations at the southern end of the valley, appear to have played a role in the 1993 slide (Kappel et al., 1996; Pair et al., 2000). Landowners in the landslide vicinity find this conclusion to be unsettling because a landslide caused by human activity could be prevented from recurring through mitigation procedures, whereas one resulting from natural conditions cannot. Residents along Tully Farms Road cannot easily mitigate the landslide hazard. Furthermore, homeowner insurance does not cover landslides and is available only as part of flood insurance; thus, financial reimbursement cannot be guaranteed in the event of another landslide.

5.3. The age of the Webster Road paleolandslide makes no difference—what about the next time it rains?

Public reaction to the paleolandslide studies has been varied. Most landowners interviewed thought that these results were interesting—one said it was of "academic" interest—but most felt that the study did not pertain directly to current problems in the Tully Valley. They also felt that the possible relationship between the Webster Road landslide and climate change offered little reassurance. Furthermore, a landslide 6100 years ago clearly was unrelated to human activity—a reminder of their inability to anticipate or prevent landslides in this area. The public would have preferred to learn of some means of prevention, mitigation, or real-time warning for residents still living at the base of Bare Mountain.

6. Implications for public policy and planning

Landslide studies in the Tully Valley have yielded a variety of data related to the cause of the 1993 landslide, the history of landslides in the region, and the likelihood of future slides. These investigations, and the public's reaction to their conclusions, exemplify several challenges faced by scientists working in the "public eye" on hazard-related problems. Several observations and suggestions are listed below; although they are specific to the Tully Valley, they could have applicability for other geomorphic investigations and hazard studies.

(i) The public's perception of risk is based on facts, but many geomorphic studies do not yield information that can be used for risk assessment analyses. Studies of landslide hazards present this type of uncertainty (Morgan, 1997). In this context, communicating the risk of future landslides to the affected community is particularly important. The landslide susceptibility map was presented and explained to local governmental officials; it was publicized in local newspapers; and it appears to have been initially used in some land-use planning decisions. However, the perception of the map as little more than a model and the infrequency of large landslides in this region underscore the need for continuing, and possibly increasing, efforts in educating the public about the methods and data used for this type of risk assessment.

(ii) The landslides in the Tully Valley are the result of several processes exceeding a threshold and culminating in a rapid and irreversible change. Indeed, many geomorphic processes involve thresholds and others have shown that thresholds are very important (cf. Coates and Vitek, 1980). However, geomorphologists need to export this concept and communicate its significance to the public. This has been accomplished in several areas of the country and through publications, e.g., Wilshire et al. (1996), but should be expanded to include the widest possible range of geologic processes.

(iii) The response of landowners presented with the conclusion that the landslide was caused by natural processes related to unusual weather conditions was generally negative. Although the type of conclusion reached here is readily accepted in relation to tornadoes or floods, it is not well received in relation to infrequent surficial processes such as landslides. The public has a perception that most landslides can be mitigated, but the Tully Farms Road area has had no land-use changes, unsafe building, or construction practices to which the landslide activity can be attributed. Further, the public's increasing awareness of the role of climate change in modifying the earth's surface (Dickinson, 1995) raises concern that the unusual weather conditions identified as the primary cause of the Webster Road and Tully Farms landslides will become increasingly common. As scientists, we can only acknowledge this concern and endeavor to put these types of events in the context of geologic time and its inherent variability.

(iv) One particular homeowner identified another failure of the landslide-related investigations in the Tully Valley. This individual's view was that the work to date had "no relation to what he needed to know." Specifically, his home had lost its potable water source shortly after the 1993 landslide and, as of this writing, his family still does not have a water supply. This suggests that attention should have been focused earlier on the water-supply issues.

(v) Finally, we cannot have "a geomorphologist on every corner" and therefore need to communicate our knowledge (and limitations) and train the public to recognize the geomorphic signs of impending hazards. This approach has been effective in the Tully Valley. Public meetings convened by the town of LaFayette and the wide distribution of a USGS Fact Sheet (Wieczorek et al., 1998) have helped landowners in the Tully Valley and elsewhere to recognize the signs of land movement, and they have provided instructions on whom to inform of changes in the land surface or water quality. By directly engaging the community in monitoring the conditions and developments in the Tully Valley, this type of "hazard stewardship" has become an effective means of addressing the continuing landslide hazard. This may be a cost-effective way of increasing public awareness of the hazardous conditions and could be beneficial in other areas.

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